Sex determination using mandibular ramus flexure in South Indian population - A retrospective study

Anuja Premkumar[1], Nagabhushana Doggalli[2], Sushma Rudraswamy[3], Bhari S. Manjunatha[4], Syed Wali Peeran[5], Abraham Johnson[6], Karthikeya Patil[1]

[1]Dept. of forensic odontology, Dental College and Hospital, JSSAHER, Mysore. India. [2]Dept. Of Oral Medicine and Radiology, Dental College and Hospital, JSSAHER, Mysore. India. [3] Dept. Of Public Health Dentistry, Dental College and Hospital, JSSAHER, Mysore. India. [4]Faculty of Dentistry, Taif University, Taif, Kingdom of Saudi Arabia. [5]Armed Forces Hospital, Jizan, Kingdom of Saudi Arabia. [6]School of Forensic Science, National Forensic Sciences University, Gujarat

Corresponding author:
dr.nagabhushand@jssuni.edu.in

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KEYWORDS

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ABSTRACT

Sex determination or sex estimation from a single or fragment of bone is always difficult in the absence of other bones from the same individual. The current study was an attempt to estimate the sex of an individual from the posterior ramus of mandible or the mandibular ramus flexure. A retrospective study was conducted using orthopantomographs (OPGs) of 200 males and 200 females between the age group of 20 – 70 years. Each radiographic image was examined for the presence of a flexure or notching on the posterior border of the ramus in relation to occlusal plane as the method followed by Loth & Henneberg 1996.The study resulted in samples that were correctly classified as females 59.5% and males 57.5 %. The overall correct sex estimation was achieved in 58.5% of the cases. The predictive accuracy or assessment was higher for females compared to males. Consequently, the posterior ramus of mandible or mandibular ramus flexure can be considered as supplementary rather than a definitive means of sex determination. Hence, it is preferable to include as many parameters as possible to attain optimal accuracy.

INTRODUCTION

Sex estimation is an essential element of anthropological and forensic research. The mandible can be a strong, dense bone of the craniofacial skeleton. Among human bones, the pelvis is the most reliable bone for sex determination. In the absence of a complete pelvis, the mandible is often used as an important means of identification. After the pelvis, the mandible is the most sexually heterogeneous bone. As shown in previous studies, various metric and non-metric parameters are used to assess mandibular sexual dimorphism.[1]

If an examiner has access to a whole skeleton, sex determination is not difficult. Both the pelvis [2, 3] and the cranium [4-6] yield extremely precise data. However, even for an expert, analysing sexual dimorphism in an incomplete or fragmented skeleton can be challenging. In addition to the pelvis and cranium, the mandible is regarded as a useful feature for determining the sex of an unknown skull. Since the beginning of the twentieth century, the utilisation of mandibular measurements began to be investigated [7-13].

Non-metric or visual indicators of the mandible are evaluated quickly and easily by comparing them with index parameters. Metric parameters cannot be used for mandibular fragmentation due to trauma. The dense bone of the lower jaw

helps to maintain its shape for a long time. The shape of the mandible can change depending on chewing habits and lifestyle. Therefore, different ethnic groups may have differences in the shape of the lower jaw. Panoramic radiography and lateral cephalography are methods commonly used in routine dental practice to evaluate important structures of the mandible and maxilla. These radiographs are suitable for checking the integrity of tooth tissue and are frequently used as tools for ramus flexure analysis to determine sex.[1]

The examination of morphologic features led to discovery of distinct angulations of the posterior border of mandibular ramus at the level of occlusal surface of the molars in adults which was termed as flexure that refers to "the quality or state of being flexed." Mandibular ramus flexure, discovered by Loth and Henneberg in 1996, has drawn worldwide attention due to its exceptionally high accuracy in sex estimation. According to Loth and Henneberg the distinct flexure is present in the posterior border of ramus at the level of occlusal surface of the molars in adult males and is not seen in females, if present, it was either above or below the occlusal surface. With this background, the current study is undertaken to evaluate the validity and predictive accuracy of mandibular posterior ramus flexure in sex estimation. [14]

MATERIALS AND METHODS

The present study titled "Age Estimation and Sex Estimation using Ramus Flexure - A Retrospective Study" was conducted in the Department of Forensic Odontology, JSS Dental College and Hospital, Sri Jagadguru Sri Shivarathreeshwara Academy of Higher Education and Research (JSSAHER), Mysuru, Karnataka.

This study was undertaken with the aim of establishing certain mandibular parameters as criteria, thereby setting a population specific standard for age and sex estimation. Digital orthopantomograms (OPGs) archived in the Department of Oral Medicine and Radiology, JSS Dental College and Hospital, Mysuru were used for this study. The study sample consisted of 400 OPGs (200 male and 200 female subjects) that were divided into five groups on the basis of chronological age by decades (40 in each group for male and female subjects), in the age range of 20-70 years. Mandibular parameters namely ramus flexure were studied and assessed whether they aid in estimating age and determining sex.

Digital orthopantomograms (OPGs) were obtained from PLANMECA PROMAX SCARA 3 Digital OPG Machine, (70 kVp, 8 mA for 09 seconds), manufactured by PLANMECA OY, Helsinki, Finland, with a 1:1 ratio. The digital orthopantomograms (OPGs) were imported into Planmeca Romexis Viewer Software 2.9.2.R., and the measurements were recorded. Microsoft Office Excel (2016) sheet was used to compile the data. The statistical analysis was carried out using SPSS Software Package version 20. Panoramic radiographs with all structures clearly visible were selected.

Methodology:

Ethical clearance was obtained from JSS Dental College & Hospital's Institutional Ethical Committee (JSS/DCH/IEC/2017-18/02) prior to conducting the study. The digital orthopantomograms (OPGs) were selected based on the inclusion and exclusion criteria. The selected radiographs were imported to Planmeca Romexis Viewer 2.9.2.R software, where the mandibular parameters were digitally traced. The literature states that a very high degree of symmetry exists between the left and the right sides, therefore all measurements were made on the left side of the radiograph for uniformity. [15, 16]

Ramus Flexure: Ramus flexure is a distinct angulation present at the posterior border of the mandibular ramus. In adult males, ramus flexure is present at the level of the occlusal surface of the molars (Fig 4). In female subjects the posterior border of the ramus can be straight, or, if flexure is observed, it is found to occur at a higher point near the neck of the condyle or below the level of the teeth in cases with gonial prominence or eversion (Fig 1, Fig 2, Fig 3). This method of observation has been obtained from Susan R. Loth and Maciej Henneberg, 1996. [17] After image calibration (to obtain 1:1 magnification) the identification of the ramus flexure on an OPG, two reference lines were traced. One as a tangent to the posterior border of the mandibular ramus (RL) and the other along the cusp tips of the molars to mark the occlusal plane. This methodology has been obtained from Badran D. H. et al., 2015. [18]

Figure 1. Ramus flexure near the neck of the condyle (yellow arrow) seen in females

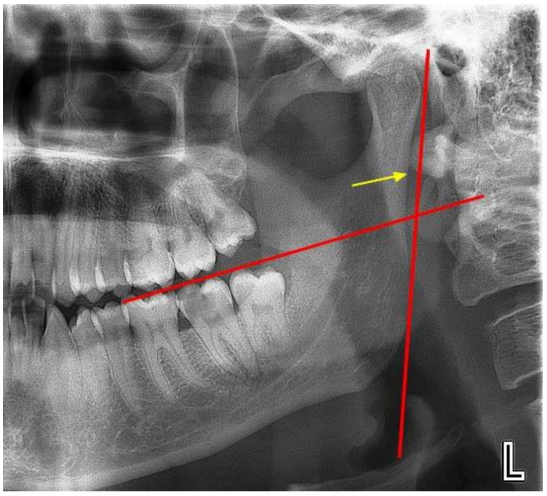


Figure 2. Ramus flexure below the occlusal plane (yellow arrow) seen in females

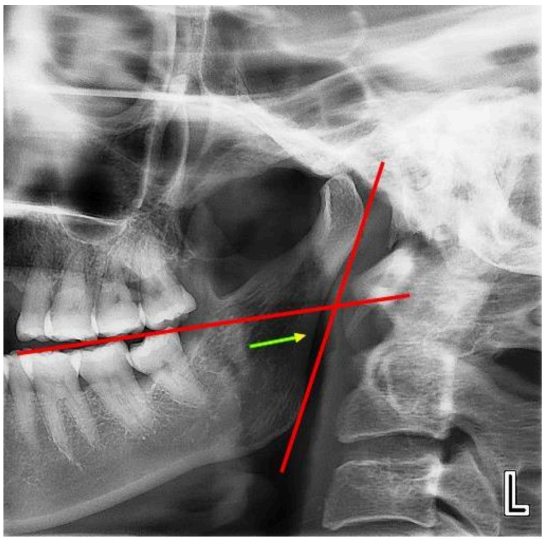


Figure 3. Ramus flexure absent (in yellow) seen in females

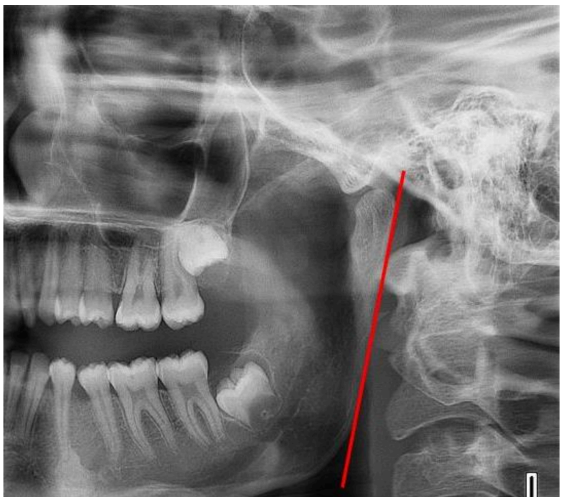
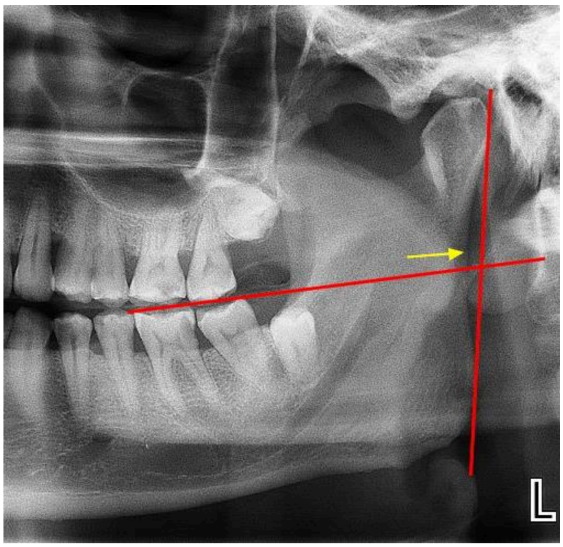


Figure 4. Ramus flexure absent (in yellow) seen in females



RESULTS

This study was undertaken to estimate age and determine sex using the mandibular ramus flexure or notch by digitally tracing measurements in Planmeca Romexis Viewer software. Ramus flexure was separately analysed for sex estimation and hence is not used in the description statistics. The measured values were entered in Microsoft excel sheet. The data was subjected to statistical analysis using SPSS Software Package 20.0. As compared and analysed with the previous national and international studies, we restricted ourselves to Descriptive statistics - mean and standard deviation were calculated. The data was subjected to independent '*t*' test and the 'P' value determined to establish the significance of the parameters in males and females.

Pre-calibration of Examiner

Data collection and exporting to the software were done by a maxillofacial radiologist who did not participate in measurement taking. All the measurements were recorded by a radiologist and a forensic odontologist and also an oral radiologist of similar experience in the field of Oral and Maxillofacial Radiology and forensic odontology. The two observers were blinded to the sex and age of the individual where no evidence of sex or age was visible in the included panoramic images. The two observers were also blinded to the measurements taken by each of

them. The mean values taken by the two observers were calculated and subjected to statistical analysis.
In order to ensure the uniformity with which the analysis was undertaken, the investigator was presented with a random set of OPGs. The agreement analysis of inter-observers had values greater than 0.89, and the intra-observer agreement analysis had values ranging from 0.85 to 0.99. Most Kappa values were interpreted to represent from substantial agreement to almost perfect agreement. The study had high values in the inter- and intra-observer analysis, showing good accuracy in the measurements made for the same person or for more than one observer.
For sex estimation using ramus flexure (Table 1, the samples that were correctly classified as females was 59.5% (119) and as males was 57.5 % (115) of the cases. The overall correct sex estimation was 58.5% of all the cases.

Table 1. Sample size distribution

Study Groups	Age group	Male	Female
Group 1	20-30 years	40	40
Group 2	31-40 years	40	40
Group 3	41-50 years	40	40
Group 4	51-60 years	40	40
Group 5	61-70 years	40	40
	Total	200	200

DISCUSSION

A distinct angulation of the posterior border of the mandibular ramus is termed ramus flexure. This distinct angulation present at the level of the occlusal surface of the molars is seen in adult males. In most females, the posterior border of the ramus is straight (also seen in juvenile mandibles) or, if flexure is observed, it was found to occur at a higher point near the neck of the condyle or below the level of the teeth in cases with gonial prominence or eversion.

It is also important not to confuse a strongly but gradually arched or curved upper ramus and condylar neck, with the distinct angulation of true ramus flexure. [5] In the present study, the classification table correctly classified females in 59.5% and males in 57.5% of the cases. The overall accuracy of correctly classifying ramus flexure was 58.5%. Comparison of percentage of accuracies for sex estimation using ramus flexure is shown in Table 2.

Table 2. Prediction analysis of sex estimation using ramus flexure

Classification Table					
	Observed		Predicted		
			Sex		Total
			Female	Male	
Step 1	Sex	Female	119(59.5%)	81 (40.5%)	200
		Male	85 (42.5%)	115 (57.5%)	200
	Overall Percentage %		58.5%		400

A panoramic radiograph (also known as an orthopantomograph) is widely available and routinely used in clinical practice to evaluate important bilateral mandibular structures. Some investigations showed that the most accurate panoramic measurements were obtained from horizontally

oriented linear items. [19] Moreover, other tests demonstrated that the accuracy and reproducibility of the vertical measurements were adequate when a software-based calibrated measurement instrument was utilised. [20] Comparing ante-mortem and post-mortem radiographs is one of the pillars of forensic anthropology for positively identifying human remains. Hence, ante-mortem orthopantomograms may be extremely useful in identifying human remains. [21] Possessing an abundance of panoramic radiographs affords a significant opportunity to examine sexual dimorphism and age estimation in a given group. This was the reasoning behind employing panoramic images for mandibular ramus evaluation in the current study

Previous studies have been conducted on OPGs as well as mandibular bone, so both methods can be used as reference for sex determination respectively depending on the type of samples available. If the skull is available, panoramic radiographs of the skull can be taken for analysis. Observations of previous researches conducted on various populations with different sample type used as presented in Table 3 can be observed for variations.

Table 3. Observations of previous researches conducted on various populations

Studies	Sample Type Used	Population	Males	Females	Overall
Present Study , 2021	OPG	India	57.5 %	59.5%	58.5%
Nivia M, 2021 [1]	Lateral Cephalogram	India	59%	87%	-
Asma Maniyar, 2021 [14]	OPG	India	44%	84%	-
Altaf 2019 [28]	OPG	India	80%	95%	-
Leena James 2019 [29]	OPG	India	63.5%	64.6%	-
Amin 2018 [18]	OPG	Jordan	78.9%	85.1%	82.2%
Thais Torralbo 2017 [30]	Mandible	Brazil	53.34%	46.66%	-
Damera A 2016 [31]	OPG	India	82.5%	85%	83.8%
Samatha 2016 [32]	OPG	India	53%	60%	-
Bibhuti 2016 [33]	Mandible	India	68.57%	43.33%	61%
Badran, D. H 2015 [18]	OPG	Jordan	95.2%	77.8%	-
Shivaprakash 2014 [34]	Mandible	India	80%	71%	76%
Indira, AP 2012 [35]	OPG	India	76%	76%	76%
Oettle A C 2005 [36]	Mandible	South Africa	69.6%	67.8%	-
Y. Balci 2004 [37]	Mandible	Turkey	95.5%	60.0%	90.9%
Loth & Henneberg 1996 [17]	Mandible	Africa	99.1%	98.8%	99.0%
Susan Jones Haun 2000 [38]	Mandible	South Africa	96.3%	62.5%	80.4%
Krogman 1940 [39]	Mandible	Iran	82.4%	55.0%	72.2%

The study by Susan R. Loth and Maciej Henneberg (1996, 200 mandibles, 116 males and 84 females, South African population) revealed a 94.2% overall accuracy which they say is on a par with the pelvis and superior to the 90% accuracy rate from a complete skull. [17] In a study conducted by Badran D. H. et al., 2015 [18], 419 Orthopantomographic (OPG) images in a

Jordanian population, an overall diagnostic accuracy of 70.9% was observed. The ramus flexure was more accurately diagnostic for females (94.6%), than for males (47.6%). [18] In Saini et al.'s 2011 [22] study, (112 mandibles, North Indian population) ramus flexure was assessed and the results showed an overall accuracy of up to 82%. [22] In the present study 78.5% (157) female subjects and 58.5% (116) male subjects were correctly classified. While most studies show a moderate level of accuracy with sexing using ramus flexure, the present study reveals a low level of accuracy in sex determination. This could be due to the presence or absence of ramus flexure, on only the left ramus of the mandible in the present study. In Loth and Henneberg's study (1996), the ramus flexure was assessed on both the right and left ramus of the mandibles. [17] Another explanation could be due to the fact that the samples in the present study consisted of several cases of partially dentate and a few edentulous OPGs. Tooth loss is also known to alter jaw morphology (Brace and Mahler, 1971; Daegling, 1993). The study suggests that the loss of even one molar may result in African females remodelling to either the male ramus shape or an intermediate configuration. [17] Mandibular tooth loss of many posterior teeth inevitably led to incorrect occlusal plane delineation and gender misdiagnosis in the study by Badran et al.[18] The loss of posterior teeth in the upper or lower jaw does not only lead to displacement, misalignment and rotation of adjacent and opposing teeth in occlusion, but it also alters the pattern of the masticatory muscle action and their effect on the eating habit and distribution of the occlusal load which, in turn, induces irregular bone resorption and may interfere with remodelling and reshaping of bone[18]. Also, substantial post-maturity growth is known to occur in the ramus (Walker and Kowalski, 1975) and elsewhere between the ages of 18 and 27 (e.g., Lubicka, 1944; Hulanicka and Kotlarz, 1983; Roche, 1989). Mandibular morphology is influenced by both masticatory muscle configuration (e.g., CwirkoGodycki, 1928; Strzalko, 1970; Malinowski, 1971; Weijs and Hillen, 1986) and changes in skull shape (e.g., Cheverud and Midkiff 1992; yEdynak and Iacan, 1993). Thus, the formation of flexion may be the result of a change in the size, strength, or angle of the masticatory muscles, especially the masseter and medial pterygoid muscles, which attach just below the level of ramus flexure. Several studies have challenged the validity and predictive accuracy of ramus flexure.(Koski et al., 1996; Oettlé et al., 2005; Hu et al., 2006).

The researchers disagreed with the prediction of ramus flexure sensitivity for both sexes. Some researchers believe that this method has a higher predictive accuracy for men than women (Donnelly et al., Kemkes Grottenthaler et al., 2002; Balci et al.; Oettlé et al.; Shivaprakash & Vijaykumar), while others have suggested that this method is more diagnostically sensitive in women (Suazo et al; Tamer, 2012) as quoted by Oksayan R 2014. [23] The evaluated sex prediction method was more diagnostic for females in the study conducted by Badran D.H et al 2015. [18] These results are similar to those obtained by the present study as well as other studies. [22, 24]

Several studies have found that this method has a higher predictive accuracy for men than for women. [24] Females reach puberty earlier than males, and this may explain why the assessed sex predictor of sexual dimorphism is more diagnostic for females. Changes in the shape of the mandible affected by the force of the muscles, especially the elevator muscles determined during patterning of the mandibular ramus, are maximal in young adults (Koski). During active growth, the mandible, including ramus flexure, is responsive to hormonal influences and is governed, in both sexes, by the forces exerted by the masticatory muscles as cited by Badran 2015 .[18] It was stated that "the high level of dimorphism in the ramus may arise in response to sex-specific hormones in susceptible skeletal sites". [17] The influence of muscles in moulding the mandibular ramus is expected to come to a complete halt at the cessation of growth at the temporomandibular joint around the age of young adulthood. The poor performance of ramus flexure in the present study can be attributed to the subjective assumption of the exact location of flexure of the posterior margin of mandibular ramus. [18]

The sexual variations in the mandible may bear genetic, hormonal or environmental influences. Since the mandible is the last skull bone to cease growth it is sensitive to adolescent growth spurt. Due to the effect of oestrogen, epiphyseal maturation and skeletal mineralization, mandibular growth becomes stable in females at the age of around 14, while it continuous to grow for 2 more years in males making the flexure more curvature. Weaker muscle forces during

mastication may also contribute to small-sized mandibles in females. Morphological features become confounded by inter-observer differences and difficulties in standardization. Very high degree of intra- and inter-observer errors have been noted by Donnelly et al [25] and Grottenthaler et al. [26]

Thus, they considered association between ramus flexure and sex to be weak, which is in accordance with the present study. In a study conducted by Hill CA in 2000 [27], 79.1 % accuracy was obtained. However, on repeating the observations only 64.7% of the cases were accurately classified. Thus, their study states that difficulty in consistent identification of flexure, low overall accuracy, and high intra-observer error indicate that mandibular ramus flexure is an unreliable feature for sex estimation. [27] With an overall accuracy of 58.5 %, the present study recommends using ramus flexure for sex estimation with other means of identification and not as a sole parameter.

CONCLUSIONS

With an overall prediction accuracy of 58.5 %, ramus flexure can be considered as one of the parameters in sex estimation. Thus, use of ramus flexure as a sole parameter for sex estimation should be avoided. It can be used along with other morphological indicators to determine the sex for identification of an individual.

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